

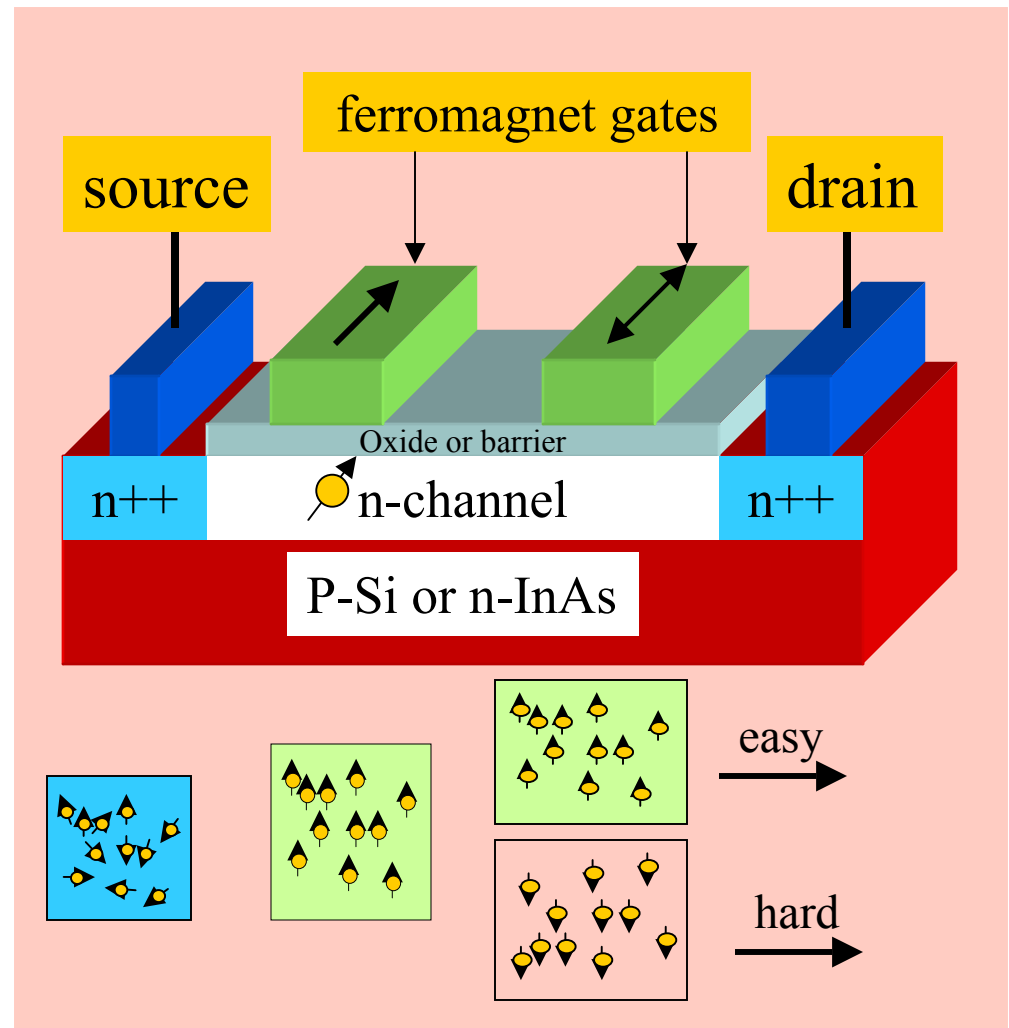
Theory of Electrons in Solids

Lu J. Sham, University of California San Diego, **DMR 0099572**

Spintronics (the spin-based electronics) utilizes both the electron charge and spin as information carrier. This design of a basic device uses the proximity of the first ferromagnet gate from the left to align the electron spins, which on entering the semiconductor from the source is unpolarized. Magnetic field control of the magnetization of the second ferromagnetic gate **parallel** (or **antiparallel**) to the first gate makes the passing of the current **easier** (or **harder**). The current can be measured when it emerges from the drain.

This suggests a direction of experimental research using the proximity effect as a means of generating and controlling spin polarization. It is a distinct alternative to the current method of tunnel injection and has the advantage of low voltage current path.

This spin-FET carries dual information, and may be the basis for a spin filter, a memory chip with a magnetic dot over the second gate, and a logic gate.



Spin FET: Ciuti, McGuire, Sham, APL and PRL

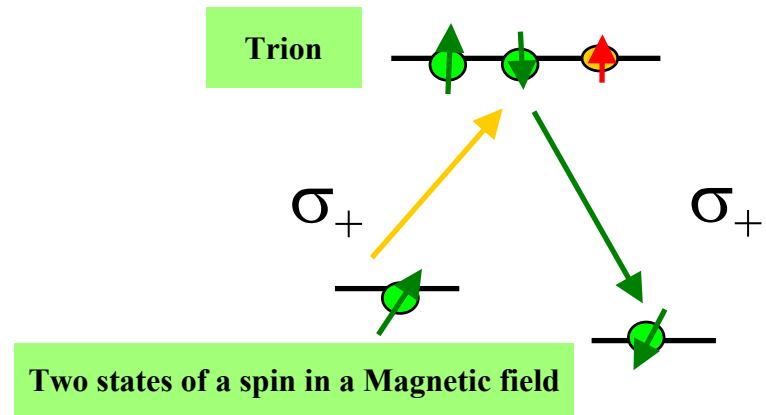
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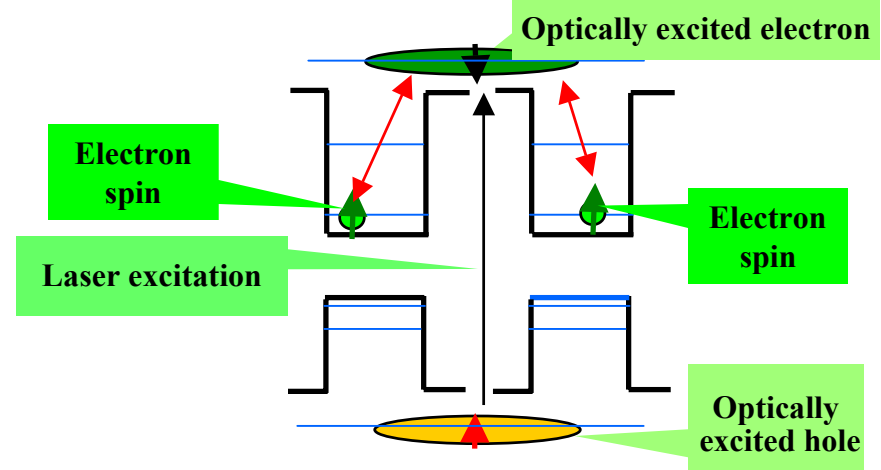
Optical control of electron spin dynamics. The upper diagram shows a method of rotating a single electron spin by laser excitation. The lower diagram shows how to switch on and off the interaction between two electron spins. An optically created electron-hole pair in the host of two localized electron spins can mediate their interaction. By a virtual creation of this pair, it is possible to switch the interaction off as the light is stopped. The theories of two possible applications based on these operations have been given:

1. **A complete scheme for universal and scalable quantum computer for a collaboration of experimental implementation in a system of semiconductor nanodots.** The quantum bit of information (qubit) is given by two spin states of one electron spin. The one and two spin operations make universal computation possible.
2. **Possible optical control of magnetism.** The rotation of an ensemble of spins and the control of their alignment are useful in spintronics.

Optical rotation of an electron spin



Optically induced spin-spin interaction



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Education and Human Resource:

James McGuire who studies spintronics is near writing his Ph.D. thesis. **Pochung Chen** obtained his Ph.D. in 2002 on "Quantum optical control of spins and excitons in semiconductor quantum dots" (for quantum computation) and is now a postdoc at University of California Berkeley. Dr. **C. Piermarocchi** who worked on quantum computation in nanodots is now an assistant professor at Michigan State University. **Wang Yao** and **Lukasz Cywinski** with a mixture of NSF and University support are starting on quantum computing and optical excitation of magnetism respectively. I have designed and taught for 4 years a graduate course in quantum mechanics from the modern perspective.

Outreach:

Contact with industry to explore possible technological applications of our ideas through special presentations on spintronics and quantum computing, such as at the 4th Engineering Invention Review Meeting at UCSD School of Engineering and on the Cal(IT)² Day at the UCSD California Institute of Telecommunication and Information Technology.

Undergraduates summer research: **Ms Yseulte Dale** from Stanford who wanted to be a science teacher (2001); **Ms Raisa Karasik** from NYU (2002) who is now a graduate student in Berkeley planning to research in quantum computers; **Mr. Allan Chang**, ECE, UCSD (2003) who is interested in spintronics.